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Proceeding

The 1st International Conference on Infrastructure Development

Infrastructure Development for Enhancing Spatial Capacity

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Preface

Praise due to Allah, the most gracious and the most merciful. The 1st International Conference on Infrastructure Development was successfully held on 1-3 November 2013 at Muhammadiyah University of Surakarta, Indonesia. The theme of this year's conference is 'Infrastructure development for enhancing spatial capacity'. This conference was organized in collaboration with the 16th international symposium of the Indonesian forum of inter universities transportation studies (FSTPT).

The conference commenced with a transportation workshop on the first day. Following the invited speakers' lectures, over 250 participants presented their papers on transportation and other areas of civil engineering which made this conference as a platform for presenting and sharing their knowledge, exchange their ideas and experience on the solution to build a comprehensive concept of constructing efficient infrastructure.

The organizing committee appreciates the efforts of the authors in providing their papers in time for these proceedings, and commends the endeavour of the program committee in producing a high quality symposium program and proceeding. The papers contained in this proceeding will provide a valuable reference source for delegates and those unable to attend the conference.

As the chairman of the conference, I want to express my gratitude to all sponsors for their commitment in supporting education of sustainable infrastructure through the generous participation in this event. I also thank to all participants for their scientific contribution and active participation in the conference, and to the steering committee, scientific committee and all members of the organizing committee who worked hard to make the conference a great success. Not to mention, the civil engineering students of Muhammadiyah University of Surakarta who participated actively in the conference.

Chairman of the conference

Dr. Mochamad Solikin

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Welcome Remark by The Head of Study Program Magister Teknik Sipil, Universitas Muhammadiyah Surakarta

Assalamu ‘alaikum warahmatullahi wabarakatuh,

Alhamdulillah, thanks to Allah the Most Forgiving and the Most Merciful for His blessing and guidance to the well arrangement of the collaboration between the International Conference on Infrastructure Development (ICID) and International Symposium of the Indonesian Inter University Transport Studies Forum. Whoever believes to Allah with powerful, then they will be helped by Allah.

ICID is the first international conference conducted by Magister Teknik Sipil UMS. This conference is designed for regular scientific meetings to provide a forum for presenters and attendees from various backgrounds to share their knowledge, exchange their ideas and experience on the solution to build a comprehensive concept of constructing efficient infrastructure and to minimize the side effect the infrastructure construction. Participants for the conference can be, but not limit to, academician with civil engineering background, stake holder, and practitioners.

The ICID is collaborated with the 16th International Symposium of the Indonesian Inter University Transport Studies Forum (IIUTSF) because at the same time Magister Teknik Sipil UMS, as IIUTSF member, is honoured as the host of Intenational IIUTSF Symposium. The ICID provides scientific forum in areas of infrastructure of civil engineering, whereas the IIUTSF is more focused in areas of transportation.

Thanks are also due to the keynote speaker, all paper contributors, and participants for their valuable contribution in this conference. I am extremely grateful to all committee members under the leadership of Mochamad Solikin, PhD for their enthusiasm and work spirit constructively. Thanks to all sponsors who support this event. Finally, I would like to congratulate for the commemoration of the 55th anniversary of Universitas Muhammadiyah Surakarta.

Thank you,
Wassalamu ‘alaikum warahmatullahi wabarakatuh.

Ir. Sri Sunarjono, MT., PhD.
The Head of Study Program, Magister Teknik Sipil UMS.

Welcome Speech by Rector
Universitas Muhammadiyah Surakarta

Assalamu ‘alaikum warahmatullahi wabarakatuh,

Alhamdulillah, all praise and thanks are due to Allah. Almighty who sustained us throughout and enable us to conduct this excellent conference. Whoever believes in compassion of Allah, then they will receive affection in the world and the hereafter.

In this noteable day, I would like to cordially welcome our distinguished the presenters and participants for their support throughout the conference. Let me also express my special thanks to Prof. Kaoru Takara from Kyoto University, Japan, and Prof. Ade Sjafruddin from Institut Teknologi Bandung, Indonesia. Special thanks are also given to the Indonesian Inter University Transport Studies Forum for the enthusiasm and constructive collaboration. I am also deeply thankful to all the sponsorship so that this conference running successfully. Finally, we are extremely grateful to the organizing committee and host you all for this excellent conference.

At present we are in the Universitas Muhammadiyah Surakarta (known as UMS) campus. UMS is education charity under Muhammadiyah organization which was established by Kyai Haji Ahmad Dahlan in 1912. Education movement of Muhammadiyah is based upon reformation and enlightenment. I think this conference is one of the important milestones in the movement education of Muhammadiyah related infratructure and transportation technology.

Currently in Indonesia, the improvement of existing infrastructure performance as well as an acceleration of constructing new infrastructure as triggers for nation development increase significantly. In other hand, the coping with frequent and various natural disasters make the Indonesian infrastructure in challenging condition.
Hence, this beautiful conference will be a forum for presenters and attendees from various backgrounds to share their knowledge, exchange their ideas and experience on the solution to build a comprehensive concept of constructing efficient infrastructure.

I am hereby proud to mention that UMS support any reformation to educate the youth of the nation and to enhance the society welfare in order to strengthen the integrity of the nation and the state. I am sure that this conference is a media to share a variety of products of academic process e.g. teaching and research activities. I encourage to all attandences to elevate the conference benefit through collaboration and partnership in a real academic program. We realize that conference only without practicing will be nothing. Practicing without systematic program will be not have much sense.

Thank you,
Wassalamu ‘alaikum warahmatullahi wabarakatuh.

Prof. Bambang Setiaji
Rector, Universitas Muhammadiyah Surakarta.

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BEHAVIOR OF FULLSCALE NAILED-SLAB SYSTEM WITH VARIATION ON LOAD POSITIONS

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Abstract

The full scale Nailed-slab System was conducted on soft clay which consisted of 6.00 m x 3.54 m slab area with 0.15 m in slab thickness, 15 short micro piles (0.20 m in diameter, 1.50 m in length, and 1.20 m in pile spacing) as slab stiffener which installed under slab, piles and slab was connected monolithically by using the slab thickening (0.40 m x 0.40 m in area and 0.20 m in thickness), then in due with vertical concrete wall barrier on the two ends of slab. The system was loaded by vertical monotonic loadings. Loading positions were varied (i.e. center of slab, edge, and interior). Results show that the installed piles under the slab which embedded into the soils were functioned as a slab stiffener and were able to response similarly in 3D. The deflection experienced very small. Nailed-slab has linear elastic response until load 160 kN. Maximum deflection and bearing capacity were not significantly influenced by load positions. Nailed-slab System is promising for practical application.

Key Words: nailed-slab, soft clay, micro piles, bearing capacity, load position.

INTRODUCTION

Rigid pavement slab on soft soils tends to experience differential settlement as the results of the differential loads distribution or differential in soil homogenous. Working load on the rigid pavement in Indonesia can be cyclic loads from traffic or temperature loads that cause the warping on the slab. These matters can cause undulating on the slab or damages on the pavement structures. Rigid pavement on soft soils needs higher slab thickness. It can be fulfilled by increasing slab thickness in conventional method then be resulted the increasing in self weight. Higher self weight of the pavement is not beneficial for soft soils. Several construction methods were developed to overcome or to minimize the rigid pavement problems on soft soils, such as soil stabilization, soil reinforcement, embankment on piles, cobweb foundation (*fondasi sarang laba-laba*), or chicken foot foundation (*fondasi cakar ayam*). Hardiyatmo (2008) proposed the changing of the shell of chicken foot foundation by short-friction piles for efficiency in construction implementation. This method is called Nailed-slab System which to be applicable for soft soils. This system consists of a thin reinforced concrete slab, and short piles attached underneath. The composite system (consists of piles, slab, and soils surrounding the piles) is expected to be formed to bear the loads. Embedded pile in the soils will nail the slab to the sub grade and the slab will remain in contact with sub grade. The installed piles under the slab also increase the slab stiffness (Puri, et.al., 2011a). Increasing the slab stiffness will decrease the slab thickness (Hardiyatmo, 2009). The decreasing of slab thickness can reduce the weight of the structure and will be beneficial for soft soils (Hardiyatmo and Suhendro, 2003). Hence, the pavement is expected to be more durable with the result that the pumping could not be taken place and differential settlement could be reduced.

Designing the Nailed-slab System is based on static load as well as designing the bridge, rather than the traffic load (axel load). A simple method to analyze the nailed-slab has been proposed by Hardiyatmo (2011). Puri, et.al. (2012b) simplified the Hardiyatmo method by considering tolerable settlement of rigid pavement. Both methods use equivalent modulus of subgrade reaction, and were also validated by model tests.

The critical load position in conventional rigid pavement is on the edge of slab. According to the Nailed-slab model, the critical load position also on the edge of slab (Puri, et.al., 2011a; 2011b). A vertical concrete wall barrier can be conducted on the slab end to reduce the deflection (Puri, et.al., 2011b; 2013b). Research about Nailed-slab System is still limited on analytical study (Hardiyatmo, 2009; 2011), model tests (Taa, 2010, Puri, et.al., 2011a; 2011b; 2012a; 2012b; 2013a; 2013b), and full scale on single pile nailed-slab (Nasibu, 2009; Dewi, 2009). This research is aimed to learn the behavior of Nailed-slab on soft clay due to loadings by conducting a full scale test. Loading positions will be varied in the center of slab, edge and interior.

TESTING INVESTIGATION

Soil Pond and Materials

Nailed-slab will be conducted on soft clay. A 6 m x 3.7 m soil pond was conducted by digging the existing soil until the depth of 2.5 m. On the 2 longer side was retained by masonry walls and supported by some temporarily girder. The anchorage system was build near the pond. Separator sheets were set on the pond walls and base to avoid the effects of surrounding existing soils. A 2.15 m of pond depth was filled by soft clay which taken from District Ngawi, East Java. The soft clay properties are presented in Table 1.

The slab and piles were reinforced concrete. The concrete strength characteristic of slab and piles were 29.2 MPa and 17.4 MPa respectively. The flexural strength of the slab was 4,397.6 kPa.

Dimension of Fullscale Nailed-slab

The dimension of Nailed-slab System was 6.00 m × 3.54 m, 0.15 m in slab thickness, and the slab was stiffened by installing micro piles underneath. Micro piles dimension was 0.20 m in diameter and 1.50 m in length. The spacing between piles was 1.20 m. All piles were installed under the slab and connected monolithically by using thickening slab connectors (0.40 m × 0.40 m and 0.20 m in thickness). Each end of slab is equipped by the vertical concrete wall barrier. There was a 5 cm lean concrete thickness under the slab. The piles configuration and other nailed-slab detail are shown in Fig. 1. Fullscale model represents a three pile rows of rigid pavement section.

Table 1 Softclay Properties

No.	Parameter	Unit	Average
1	Specific gravity, G_s	-	2,55
2	Consistency limits:		
	- Liquid limit, *LL*	%	88,46
	- Plastic limit, *PL*	%	28,48
	- Shrinkage limit, *SL*	%	9,34
	- Plasticity index, *PI*	%	59,98
	- Liquidity index, *LI*	%	0,36
3	Natural water content, w_n	%	50,49
4	Water content, *w*	%	54,87
5	Clay content	%	92,93
6	Sand content	%	6,89
7	Bulk density, γ	kN/m^3	16,32
8	Dry density, γ_d	kN/m^3	10,90
9	Undrained shear strength, s_u		
	- Undisturbed	kN/m^2	20,14
	- Remolded	kN/m^2	11,74
10	CBR	%	0,83
11	Soil classification:		
	- AASHTO	-	A-7-6
	- USCS	-	CH

Testing Procedures

The steps in construction of fullscale Nailed-slab can be briefly described as follows: the pond was filled by soft clay until the soil thickness reach 2.15 m. Soft clay was spread about 15 cm in thickness per layer with controlled water content, and then it was compacted by 3 passing of manual compaction. Each soil layer thickness was decreased to about 10 cm per layer. Soft clay was cured by covering its surface with plastic sheet and wet carpet. Some soil investigations were conducted, i.e. soil boring, vane shear test, CBR test, and plate load test. After that, 15 concrete piles were driven by pre-drilled method and then continued by hydraulic jacking until the pile top reach the design level. Two piles were instrumented for measuring surface concrete strain and rebar strain. Some piles were tested for compression bearing capacity, tension capacity, and lateral bearing capacity. Soil was excavated for thickening slab and also assembled 4 pressure meters on soil surface in deferent location. The 5 cm lean concrete then poured on the soil surface, and continued by conducting CBR test and plate load test after 3 days. The slab and vertical wall barrier reinforcement rebar were assembled and included with setting up strain-gauges. And then concrete was poured for slab and taken slump test, cylindrical concrete specimens, and also concrete pouring on slab specimen mould for flexural tests. Slab was cured by wet carpet and after 28 days of concrete age the loading set up was assembled. Loading test was conducted on the slab for different load position. Loads were transfer to the slab surface by using circular plate with 30 cm in diameter (the plate represents the single wheel load contact area). Then the instrumentations were recorded. Some photographs in construction and testing were presented in Fig. 2 and 3.

RESULTS AND DISCUSSION

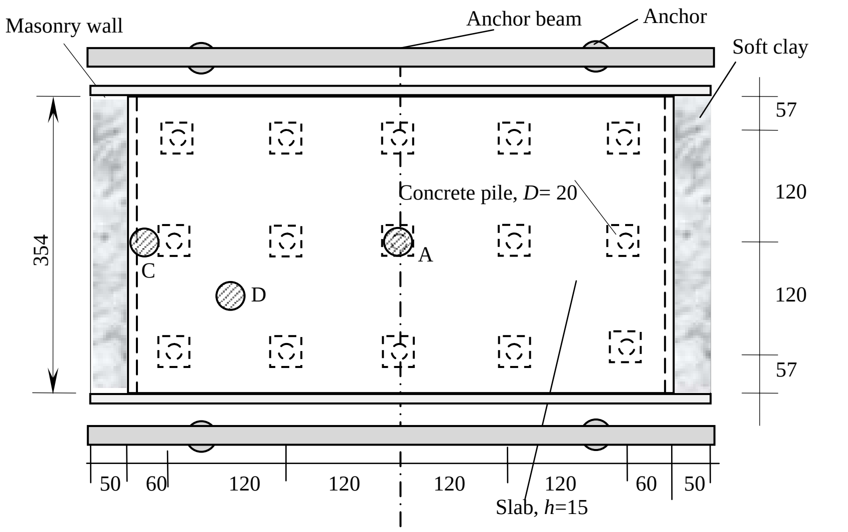
Loading Test Results

In this paper, loading test results will be presented for 3 loading positions, i.e. centric load (point A), edge load (point C), and interior load (point D). Every load points were not loaded until failure, except reach the early of plastic zone.

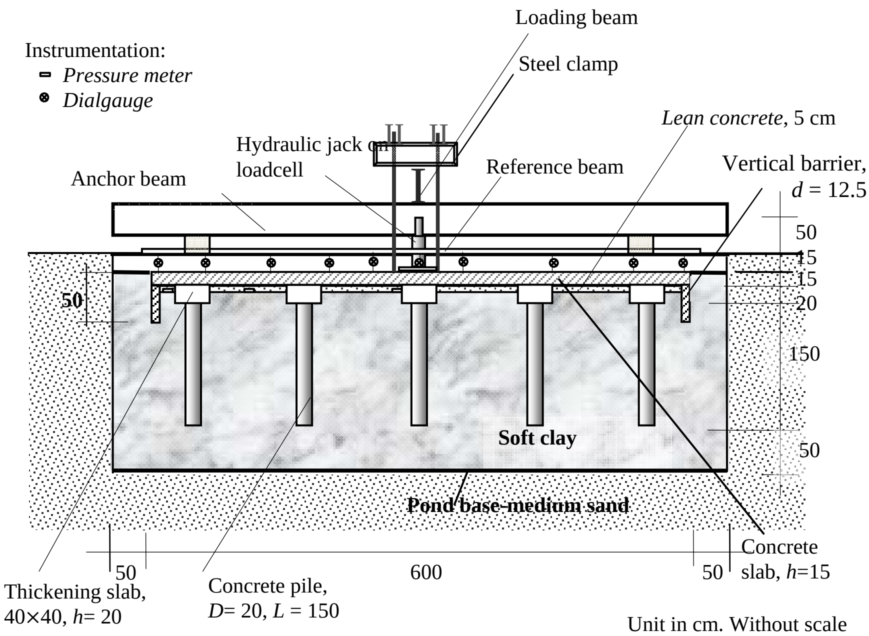
Centric loads (point A)

The increment load was two times the previous loading. Loading intensity was began at P = 0 kN, then increased to P = 5 kN, 10 kN, 20 kN, 40 kN, 80 kN, 160 kN, and 220 kN (±5.5 x 40 kN design single wheel load for highway) respectively. Then, loading intensity was decreased gradually from P = 220 kN became P = 80 kN, 40 kN and 0 kN. The P- relationship for centric load is presented in Fig. 4a. It can be seen although the load reached 220 kN (±5.5 x 40 kN design single wheel load), the maximum deflection occurred on the load point is still small (about 4.20 mm). The maximum bearing capacity of the tested Fullscale Nailed-slab is much greater than 220 kN (expected 427 kN, simply calculated from 20.14 kPa x 21.24 m^2) which is indicated by the curve a long way offs the asymptote. But then the non linear response is occurred at load 160 kN. The linear response is clearly seen at the curve for load smaller than 160 kN, which the load 160 kN is quite enough (reached ±4 x 40 kN design single wheel load). So, deflection due to load P = 40 kN is in linear-elastic zone. Deflection responses for others points are not discussed since they have smaller deflection values.

Fig.5 shows deflection shape along the slab (cross section in field condition). It is seen that deflection shape is a bowl shape and Fig.4b also shows this phenomenon. This phenomenon fulfilled the expectation that the more and more from loading point the deflections tend to experience smaller. It indicates that all piles gave good response and the system (installed micro piles, concrete slab, and thickening slab which connected the pile and slab) worked perfectly. However, the end of slab was experienced relatively insignificant settlement. That is the observation for all loading intensity. In case of standard single wheel load 40 kN (in load pressure 566 kPa), then the settlement of the end of slab was not significantly, only about 0.10 mm. It will not be the problem for end of slab in cross section of the fullscale slab model, because the highway in the field will be constructed by longest segment compare to the road width. Nailed-slab System is suggested to construct using continuous reinforced concrete pavement. Thus the significant settlement of the end of slab in cross section of the prototype will be very significantly reduced in field application.



a). Plan of view



b). Cross section

Fig.1 Schematic Diagram of Nailed-slab Fullscale

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a)

b)

c)

d)

Fig.2 Construction on Fullscale Nailed-slab System; a) cured soft clay on the pond, b) pre-drilled driving piles, c) concrete reinforcement, d) finishing of concrete pouring

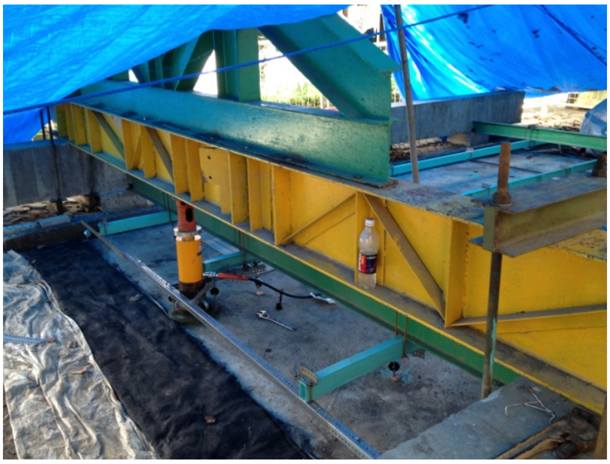
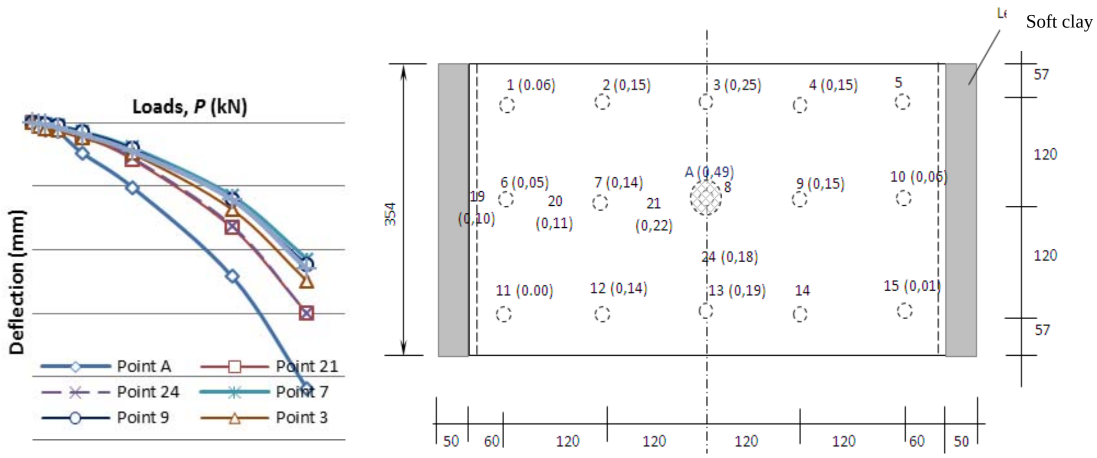


Fig.3 Loading test on the edge of slab



a. P-δ relationship b. Observed deflections at P=40 kN

Fig.4 Results for centric load. Note: distance in cm, deflection in mm (indicated by parenthesis)

According to above discussion, it can be summarized for monotonic center loading as follows: (a) Fullscale Nailed-slab has higher bearing capacity above 220 kN (expected about 427 kN), (b) linear elastic-response is kept until load 160 kN, (c) higher stiffness, i.e. at load 40 kN the deflection experienced only 0.49 mm indicates that the installed piles under the slab was stiffer enough as a slab stiffener, and (d) all installed piles were able to response similarly in 3D that indicated by symmetrical deflected-bowl shape.

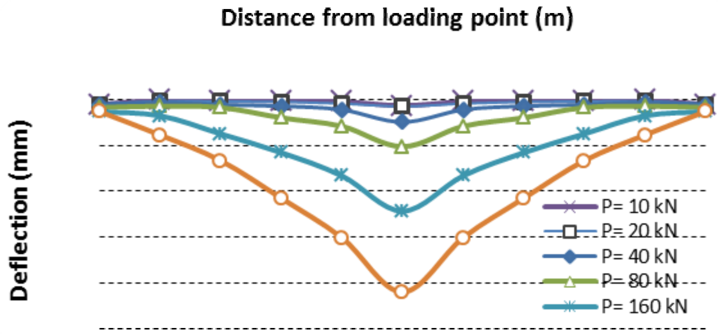


Fig.5 Deflection shape along the slab due to centric load

Edge loads (Point C)

P- relationship for edge loads is shown in Fig.6a. Loading intensity was increased gradually from P= 0 kN, then became respectively P = 5 kN, 10 kN, 20 kN, 40 kN, 80 kN, 120 kN, and 140 kN (±3.5 x 40 kN design single wheel load). Then, loading intensity was decreased gradually from P = 140 kN became P = 80 kN, 40 kN, 20 kN and 0 kN. It can be seen although the load reached 140 kN (±3.5 x 40 kN design single wheel load), the maximum deflection occurred on the load point is still small (about 3.76 mm). Furthermore, the curve a long way offs the asymptote. This indicates that the maximum bearing capacity is much greater than 140 kN. But then the non linear response is about to occurred at load 80 kN. The linear response is clearly seen at the curve for load smaller than 80 kN, which the load 80 kN is quite enough (reached ±2 x 40 kN design single wheel load). Thus, the linear response caused by edge loading is about a half of linear response of centric load. Deflection responses for others points are not discussed since they have smaller deflection values.

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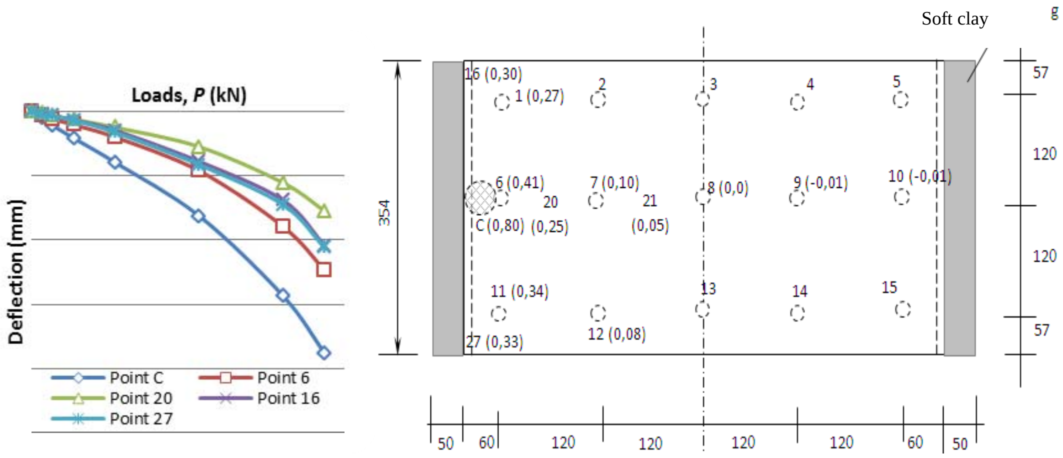


a. P-δ relationship b. Observed deflections at P=40 kN

Fig.6 Results for edge load. Note: distance in cm, deflection in mm (indicated by parenthesis)

Deflection shape along the slab (cross section in field condition) shows in Fig.7. It is seen that deflection shape is a half bowl shape and Fig.6b also shows this phenomena at loading P = 40 kN. However, the end of slab across the load position was not uplifted. It is caused by the contribution of uplift resistance from installed piles under the slab. Each corner of slab near the loading point experienced little bit significant settlements about 0.33 mm. It will not be the problem for field application. This settlement will be decreased significantly by longest the pavement length.

It can be summarized for monotonic edge loading as follows: (a) Fullscale Nailed-slab has high enough bearing capacity above 140 kN (b) higher stiffness, i.e. at load 40 kN the deflection experienced only 0.80 mm, and (c) linear elastic-response is kept until load 80 kN.

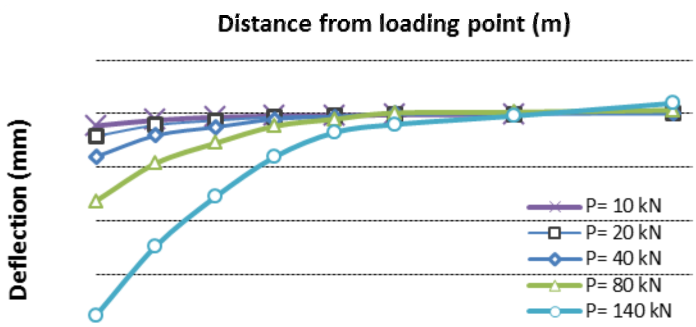
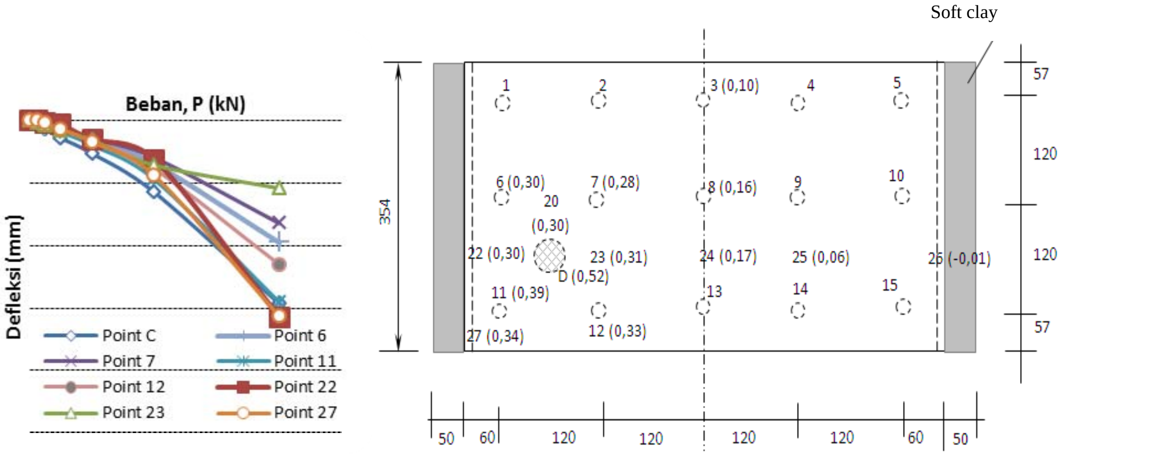


Fig.7 Deflection shape along the slab due to edge load

Interior loads

Fig.8a shows P- relationship for interior loads (point D). It can be seen although the load reached 160 kN (±4 x 40 kN design single wheel load), the maximum deflection occurred on the load point is still small (about 2.93 mm). Furthermore, the curve a long way offs the asymptote. This indicates that the maximum bearing capacity is much greater than 160 kN. But then the non linear response is about to occurred at load 80 kN. The linear response is clearly seen at the curve for load smaller than 80 kN, which the load 80 kN is quite enough (reached ±2 x 40 kN design single wheel load). Thus, the linear response caused by interior loading is similar to edge loading about a half of linear response of centric load. Deflection responses for others points are not discussed since they have smaller deflection values.



a. P-δ relationship b. Observed deflections at P=40 kN

Fig.8 Results for interior load. Note: distance in cm, deflection in mm (indicated by parenthesis)

Deflection shape along the slab (cross section in field condition) shows in Fig.9. It is seen that deflection shape closes to a bowl shape and Fig.8b also shows this phenomena at loading P = 40 kN. However, the end of slab across the load position was not uplifted. It is caused by the contribution of uplift resistance from installed piles under the slab. Each corner of slab near the loading point experienced little bit significant settlements about 0.34 mm. It will not be the problem for field application. This settlement will be decreased significantly by longest the pavement length.

It can be summarized for monotonic interior loading as follows: (a) Fullscale Nailed-slab has high enough bearing capacity above 160 kN, (b) higher stiffness, i.e. at load 40 kN the deflection experienced only 0.52 mm, and (c) linear elastic-response is kept until load 80 kN.

Differential settlement

Differential settlement for various loading position is shown in Fig.10. It can be seen that the differential settlement at single wheel load 40 kN for all loading positions are not significant. Linear elastic-response for centric load is kept until load 160 kN while for edge and interior loading are kept until load 80 kN. Centric load and edge load have similar maximum differential settlement, but they are occurred at different load intensity, and maximum differential settlement for interior loading is smallest.

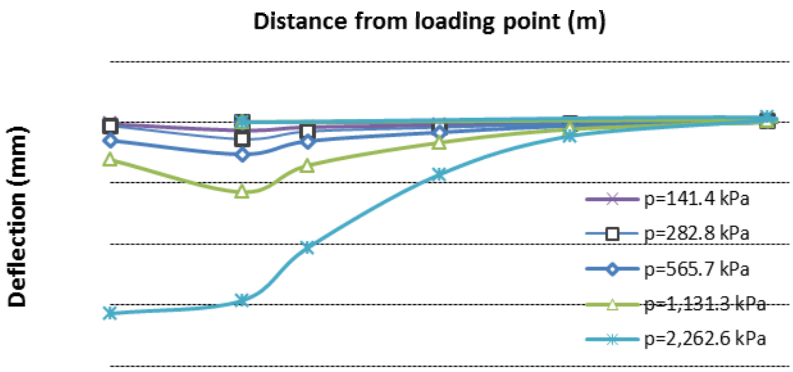


Fig.9 Deflection shape along the slab due to interior load

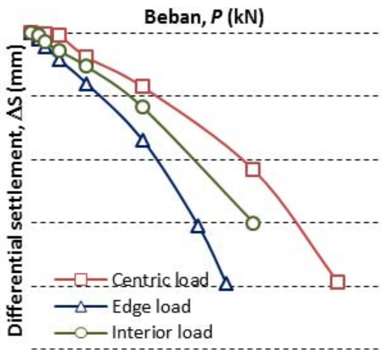


Fig.10 Differential settlement for various loading position

Strain in Concrete and Rebar

It was also conducted the observation on pile concrete surface strain and rebar strain, and soil response under lean concrete. But then the soil responses were not recorded because the pressure meter equipments were not worked. Instrumentation for monitoring the strain of concrete and rebar were installed on the pile number 6 and 7. Concrete straingauges were set up on 3 different positions; upper side of pile, middle side, and lower side near the end of pile (Fig. 11). Concrete straingauge is symbolized by CP and followed by number of pile and number of straingauge position (no. 1, 2, and 3 for upper side, middle side, and lower side respectively). CP6-1 means the concrete straingauge on pile no. 6 for upper position. Rebar straingauge were consisted of straingauge for main rebar and shear rebar which were symbolized by letter T and S respectively.

The recorded strain is shown in Fig.12 for centric load. CP6-2 and CP7-2 were not detected, instead for RP6-T. Strain on surface concrete and rebar for pile no. 7 experienced higher strain. The end of pile 7 exceeded maximum allowable concrete strain at load about 80 kN. Strain on surface concrete was about 1,400 micro strains at load 40 kN. This strain will be decreased by increasing the concrete strength. Unfortunately, strain of main rebar for pile 7 exceeded yield condition on load 20 kN, and the area of this rebar is needed to increase.

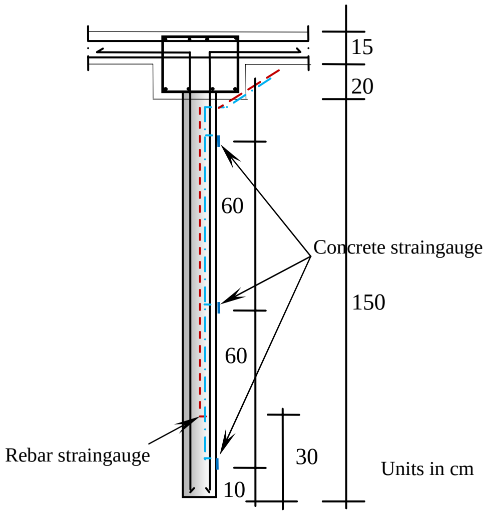
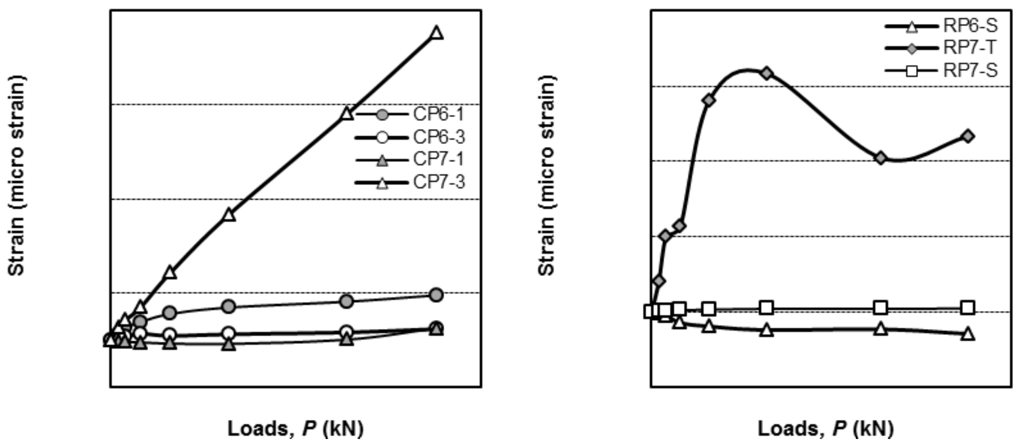


Fig. 11 Straingauge position in the instrumented pile



a. Strain on surface concrete b. Strain in rebar

Fig.12 Strain behavior on piles due to centric load

Consideration for Practical Application

Considering the results and discussion in previous section, the testing results show that the performance of Nailed-slab System is promising. This system has higher bearing capacity and installed pile under the slab well functioned as a slab stiffener. Since this system will be functioned as pavement in the field, the Nailed-slab will have extensive area and installed pile under the slab will also more and more to all directions. So the performance of this system would be better due to bearing capacity and reduction on the slab deflection.

Nailed-slab can be constructed directly on soft soils. It is necessary to strip the soil surface to avoid organic material. This system will have higher bearing capacity and stiffness, and also has no problem in consolidation settlement (because there is no embankment on soft soils, smaller slab thickness that reduce self weight, and generally the loads will be temporary loadings). In case the pavement surface level is customarily constructed higher than soil level to avoid floods, and then the Nailed-slab System can be combined with light in weight embankment materials. The Nailed-slab System can also be combined with necessary soil improvement, because this system is not about soil improvement but rather about the method to gain performance of rigid pavement on soft soils.

Using of short micro piles in the Nailed-slab System will be easier in construction and no need heavy equipments and working platform for heavy equipments passing (consists of 35 cm thickness of sub base layer and 15 cm lean concrete). With the result that it will be less in time consuming and relatively inexpensive construction cost.

CONCLUSIONS

Monotonic loading test by variation in loading position on the fullscale model of Nailed-slab System was conducted. According to loading test results and discussion, several important conclusions can be concluded as follows

1. Fullscale Nailed-slab has linear elastic-response until load 160 kN,
2. installed piles under the slab which embedded into the soils was stiffer enough as a slab stiffener,
3. piles and slab was connected monolithically by using slab thickening (0.40 m x 0.40 m in area and 0.20 m in thickness),
4. shape of deflected bowl indicated that the all installed piles were able to response similarly in 3D,
5. occurred deflection due to loading was very small (about 0.80 mm for edge load intensity P = 40 kN),
6. loading position was not significantly influence to the maximum deflection and bearing capacity,
7. it conclude the system is promising for practical application and the construction of the Nailed-slab System will be less in time consuming and relatively inexpensive construction cost by using the short micro piles.

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